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Raising Awareness at School Level for The Problem of Exposure of Populations to Noise

Nuno Domingues[1*], J. M. F. Calado[1,2], Nuno Henriques[1], Joel Paulo[1]

[1] Instituto Politécnico de Lisboa/ Instituto Superior de Engenharia de Lisboa
Rua Conselheiro Emidio Navarro, 1, 1959-007 Lisbon, Portugal
[2]IDMEC, Instituto Superior Técnico, Universidade de Lisboa

***Abstract*:** *Noise is a social problem with an impact on public health, particularly observed in urban areas, shared spaces, public transports and in the workplace. The exposure of people to noise can lead to problems such as reduced productivity, loss of health and quality of life. According to the World Health Organization, the effects of exposure to noise on people is one of the main determinants of health. The European Environment Agency (EEA) indicates that noise is responsible for 16 600 premature deaths and more than 72 000 hospitalizations every year in Europe. For the preservation of wildlif, and the health and well-being of human beings, public debates on the topic must be held frequently, and there must be campaigns to raise awareness of the populations, with special importance in the younger ages, at the level of schools. As a result, actions to monitor noise levels in specific situations/contexts/environments should be recommended, comparing the recorded values of measurements with the limits recommended/imposed by current legislation and paying attention to the noise-health relations. This study consists of proposed activities in the school environment following a pedagogical approach of Problem Based Learning, PBL, considering the issue of noise. To this end, working groups of 3 or 4 students are advice, to whom set up challenges are launched on the the theoretical understanding of 3 noise Exposure topics considered, Ambient, Neighborhood and Occupational and on practical awareness of spectrum diagram as a tool.*

With this learning approach it is expected that it will prepare youngsters to measure noise levels in diverse environments and increases their awareness of hazardous environments, sources of noise and how environmental noise can affect health and quality of life in the community.

Over 6 classes, each group develops skills/sensitivity on noise issues in general, focusing on the theme assigned to them. The approach followed consists of the presentation of the basic concepts by the teacher, namely, concepts of Sound Pressure Level, frequency, timbre, Broadband Noise, Tonal Noise, Impulsive Noise, Collaborative Learning, Study-based Learning, Questionnaire-based learning, etc., and based on internet research on the various topics of noise and a practical component where students make sound recordings in different environments, through mobile apps, inside and outside school, for further analysis and characterization. Additionally, students are provided with an online tool that allows the upload of audio files for sound reproduction and analysis based on histograms, spectra and noise spectrograms, allowing the characterization of noise based on sound levels along the frequency bands. This tool also displays a table with associated public health risks for different noise levels along each frequency band, and noise exposure time, based on scientific studies and legislation.

Keywords: *Environmental Noise, Neighbourhood Noise, Occupational Noise, Noise Exposure, Problem Based Learning, Project Based Learning, Study-based Learning*

1. Introduction

"Exposure to high levels of noise for long periods of time can result in hearing loss: first partial and then complete (...). Noise produces psychophysiological effects, such as stress. In addition, it may result in elevation of cholesterol, triglycerides and elevation in blood pressure" [1].

Pao-Chiang Chao et al. (2013) states that excessive exposure to noise can affect organs beyond hearing [2]. Excessive stimulation of the autonomic nervous system and the nervous network of the cerebral cortex leads to extreme stress, which in turn gives rise to an accelerated and irregular heartbeat, a considerable increase in blood pressure, muscle contractions that can lead to fatigue and reduced sensitivity to light. In addition, this author highlights factors that directly determine the severity of hearing loss, namely, noise level, exposure time, noise and frequency characteristics, and the difference in the human characteristics of those exposed, such as the individual sensitivity of each one.

Exposure to noise can also produce consequences with some harmfulness related to stress, in order to release "catecholamines that prepare the organism for rapid reactions", it can also cause an increase in blood pressure (directly related to the intensity of the noise), potentiation of atherosclerosis (after chronic exposure) and "change in the functioning of the myocardial structure".

All negative results in the human body thus define noise as the cause of excessive stress in the autonomic nervous system (Santos & Almeida, 2016). Exposure to high levels of noise can produce, in addition to pathologies and physiological changes, as well as psychological disorders, for example, excessive anxiety, depression, irritability, nausea, migraines, chronic tiredness, insomnia, as well as sudden changes associated with aggression and hostility [3].

The WHO (2018) indicates ambient noise as one of the main current risks to the physical and mental health of urban populations. The publication claims that people exposed to high levels of noise for a long time demonstrate psychological and physiological suffering, as well as 'homeostasis disturbances', which means that the body loses synergy or functioning balance, generating instability in the physiological processes of the human body, such as changes in body temperature, increased fluid volume, cardiac arrhythmia, among others. Among the most dangerous diseases caused by such exposure, the publication highlights: "cardiovascular diseases, cognitive impairment in children, sleep disorders, hearing disorders, tinnitus and boredom" as well as a decrease in quality of life, well-being and mental health, when at exposures above 55 dB(A) it becomes constant and frequent.

The awareness and training of civil society in relation to the noise issue is a matter of the utmost importance to be aware of the rights and duties that each citizen has in order to improve people's quality of life. In order to obtain better results in the medium/long term, this sensitization should be carried out at a young age. The different strategies to sensitize people is by Improving knowledge (to inform people about an issue and make sure that they have the correct information to truly understand the issue), changing attitudes (change people's behaviour or attitudes towards the issue by explaining to them how new behaviours and attitudes will reduce bad impacts and/or introduce good impacts) and focus on skills (promote critical mind on analysing data and enhance communication skills to disseminate the knowledge).

The teaching-learning methodology helps students to understand this public health issue and to understand how STEM (Science, Technology, Engineering, Mathematics) contributes to addressing and tackling major public health challenges and contributing to decision making, personal and political.

This study explores the most important influences of noise on human health, and assigns valences to prevent noise-related diseases, creating awareness about healthy lifestyles, social and environmental influences and risk factors.

2. Suggested Methodology for Group Activities

The research, based on a scientific methodology, is the first stage proposed. Scientific methodology is the sum of certain rules and procedures of an academic work with the objective of systematizing and bringing clarity to

scientific research. Thus, the researcher must respect the entire research process, seeking the best methods through steps, such as:

- Definition of data acquisition techniques
- Data collection
- Display and organization of the results obtained
- Analysis of results

Then a project philosophy follows. The teams involved in a project, including the Project Manager, tend to focus their efforts on the production of the handouts (final products) in order to successfully achieve the objectives of the project. However, the project's handouts are only a means to an end. The real purpose of a project is to achieve certain results, which allow to generate measurable benefits. It is essential to adopt a Methodology in which all those involved in the management and execution of a project (managers and team members) understand the relationship between products, results and benefits of the project. Design products (deliverable) are products/services that introduce something new (a change). The change introduced will produce a result. The benefits are measurable improvements as a result of this result.

To embrace this approach, there is a problem to solve or a research question to be answered, defining the problem-based learning. Problem-Based Learning is a teaching methodology that promotes active student-centered learning, confronting them with complex real-world problems. Students are led to problematize, reflect and assign meaning to their learning as they find the answers to the problems presented to them. In this sense, this methodology, in addition to promoting essential competencies for lifelong learning, stimulates critical thinking, collaboration, creativity and communication.

The noise issue is addressed in the school environment following a pedagogical approach of Problem Based Learning, PBL. To this end, students working groups will work on 3 noise topics considered the most important on our society, Ambient Noise, Neighborhood Noise and Occupational Noise Exposure.

Each group develops skills/sensitivity on noise issues in general, focusing on the theme assigned to them. The approach followed consists of the presentation of the basic concepts by the teacher, namely, concepts of Sound Pressure Level, frequency, timbre, Broadband Noise, Tonal Noise, Impulsive Noise, Collaborative Learning, Study-based Learning, Questionnaire-based learning, etc. ., and based on internet research on the various topics of noise and a practical component where students make sound recordings in different environments, through mobile apps, inside and outside school, for further analysis and characterization.

A tool that supports upload of audio files and displays histograms, spectrograms, frequency, and amplitude values is made available for the students. A table with identified and expected risks is developed for each frequency, amplitude, and duration time, based on scientific studies. Therefore, the learning experience prepares youths to measure noise levels and become aware of risky environments, sources of noise pollution, and how this threat can influence the health and quality of life of the community.

It also supports students' participation in civic society initiatives and in the design of local responses for the issue, while providing significant interactions with the community and STEM related professions (researchers, noise specialists, data scientists, policy makers, enterprises). The scenario is based on the mandatory curriculum of natural sciences at EU level and promotes the following fundamental learnings:

- Presents the basic concepts about sound and noise, making their distinction;
- Distinguishes between noise in the main contexts: Ambient Noise, Neighborhood Noise and Occupational Noise Exposure;
- Characterize the main diseases related to noise, indicating the prevalence of associated risk factors;
- Uses existing legal mechanisms, namely the Regulamento Geral do Ruído, RGR (portuguese Law of Noise), Directive 2002/49/EC - Environmental Noise Directive (END), Regulamento dos Requisitos Acústicos dos Edifícios, RRAE (portuguese recommendations for building facade insolation) and

Directive 2003/10/CE, on the minimum safety and health requirements regarding the exposure of workers to risks due to physical agents (noise), to support decisions and actions to mitigate the noise;

- Interpretation of the information on the determinants of individual and community health, analysing their importance in the quality of life of a population.

2.1. Spotlight

The most important topics considered in this analysis regarding sound are:

- Correlation, from experimental activities, the intensity, pitch, and timbre of a sound with the characteristics of the waveform and identification of pure tones and impulsive sound events;
- Interpretation of noise spectrum graphics, identifying the level of sound intensity and the threshold of hearing and threshold of pain;
- Identification of noise sources, in different environments, using sound level meters, and based on research, critically evaluate the consequences of noise on human beings, proposing prevention and protection measures;
- Incidence of diseases related with high noise levels exposure;
- Action supporting health promotion and disease prevention in the community.

2.2. Research Management, Design and Administration (Summary Topics)

- Identification of daily environments where noise is clear;
- Decide for daily environments where noise pollution is not considered a problem;
- Record sounds in some places, considering the 3 noise contexts: Ambient Noise, Neighborhood Noise and Occupational Noise Exposure;
- Define and insert data in the online tool;
- Promote reflection and discussion on risks and protective behaviour;
- Aid in the report elaboration that will be available in the repository platform.

2.3. Challenge

Build an infographic about Noise Pollution: Consequences and Measures!

2.4. Development Process

Building upon the knowledge acquired in previous classes, and by following inquiry-based approach, students will carry out a practical activity that involves sound measurements in different contexts within the school environment. In the first instance, students will study the different noise contexts they may encounter in the school environment (e.g.: ambient noise related to traffic noise, or neighborhood noise related to the transmission of sounds between houses or rooms). In addition, the measurement device that students will use to perform the activity is introduced.

Subsequently, students carry out a series of sound measurements at school, in different contexts, and also register certain parameters such as the location, duration and noise source of each measurement they conduct. Then, students analyse the recorded data, having to identify, from the sound measurements they registered, those that are considered noise, considering the parameters that characterize sound (e.g.: frequency (Hz), sound level (dB)), and the recommended limits/legislation of sound level in each context. To carry out this task, students use the online tool that allows the upload of each measurement recorded with the mobile application and the conversion of these audio files into a noise spectrum diagram. Additionally, the tool also presents a table with a series of risks to public health considering the sound levels/frequencies recorded. After analyzing the data, students discuss among themselves the results obtained in the measurement activity and propose a series of measures to be applied both individually and at the community level to mitigate the effects of noise, in each context. These debates can be held at school, or in the science club. Another activity is also planned in which students and teachers visit the laboratory of Audio and Acoustics of ISEL to highlight sound/noise issues by carrying out live experiences related to sound. Additionally, some demonstrations will be implemented.

The study outputs will be a scientific poster/presentation related to each context of noise approached, namely, Ambient Noise, Neighborhood Noise and Occupational Noise Exposure, including the basic concepts of the sound, and it should include the content of the brief reports the students analyze throughout the study regarding the noise, and an infographic regarding each of the 3 contexts used in the study, and the measures to take place at the community level to prevent/mitigate the noise effects.

All the aforementioned resources are then presented to the rest of the school community, parents, stakeholders, etc., where each of these groups gets high-level understanding on strategies to minimize the phenomena and how they may have an influence on the relevant settings (e.g., home, school, workplace, public space at the community level).

3. Devices and Infrastructures

3.1. Sound Measurement

The sound pressure level at a distance *d*, with $\tilde{p}_{rms} = \sqrt{1/T \int_T p^2 dt}$ representing the root mean square pressure of *p*, is expressed by:

$$L_p = 20 \log_{10} \frac{\tilde{p}_{rms}}{\tilde{p}_{ref}} \quad (\mathrm{dB}) \qquad (1)$$

where p_{ref} is the reference sound pressure, human hearing threshold, (2×10^{-5} N/m^2 or 20 μPa).

There are different devices dedicated to measure the sound (or noise), based on the so called Sound Level Meters and Noise Dosimeters. Depending on the situation and the measurement accuracy needed a specific device is selected.

For legal noise assessment purposes certified devices are required. These devices are generally used by professionals, being quite expensive and requiring reasonable knowledge in the field of acoustics. However, there are many other measuring devices, which, although they do not have the same precision as those mentioned above, present very good results and can be used as a first approach by ordinary people. Nowadays we can find several apps for mobile phones that measure sound and carry out a series of analyses, in addition to measuring sound levels, noise statistics (maximum, minimum, average, histograms, etc.), noise spectrum , data storage, etc, are also calculated. Figure 1 shows examples of devices for sound analysis.

Fig. 1: Examples of devices for measuring the sound. Sound Level Meter (left most), Noise Dosimeter (right down) and Apps for mobile (left up).

3.2. Sound Analysis

In addition to broadband noise (the usual noise situation people are exposed to on a daily basis), the types of noise that most affect health are tonal noise and impulsive noise. Tonal noise because it greatly affects people's concentration, increasing irritability (even at low sound levels) and impulsive noise because it generates very high noise levels (firearms or blasting in quarries) or, in the case of low levels, by repetition (example of repetitive drops of water falling into a metal bucket), they become annoying and irritating. Figure 2 shows examples of these types of noise, in the frequency domains (noise spectra) and in time (waveform).

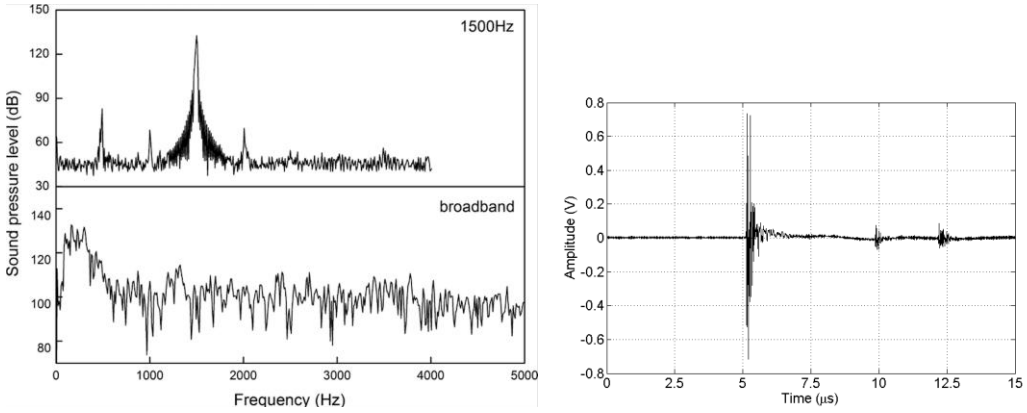

Fig. 2: Examples of noise spectra for tonal and broadband sound (left) and impulsive sound (right).

These types of sounds will be addressed in this study by the working groups, in order to gain sensitivity to analyze the various scenarios of ambient noise.

3.3. Sound experience – Laboratory of Audio and Acoustics of ISEL

The immersive sound topic has been gaining a lot of importance in recent years mainly due to the popularity of VR/AR and cinema with 3D sound (i.e. Dolby Atmos) as well as lower implementation costs. Thus, it is feasible to build fixed sound reproduction installations with multichannel speaker systems (dozens of speakers placed around a room), creating a completely immersive sound experience. This type of facilities is also of great interest for research and development purposes.

ISEL is building a room with a multichannel sound system with 40 speakers, as shown in the virtual model in Figure 3. Additionally, we are developing tools to create virtual models of architecture and acoustics, allowing the creation of a virtual experience of environments sound [4-5].

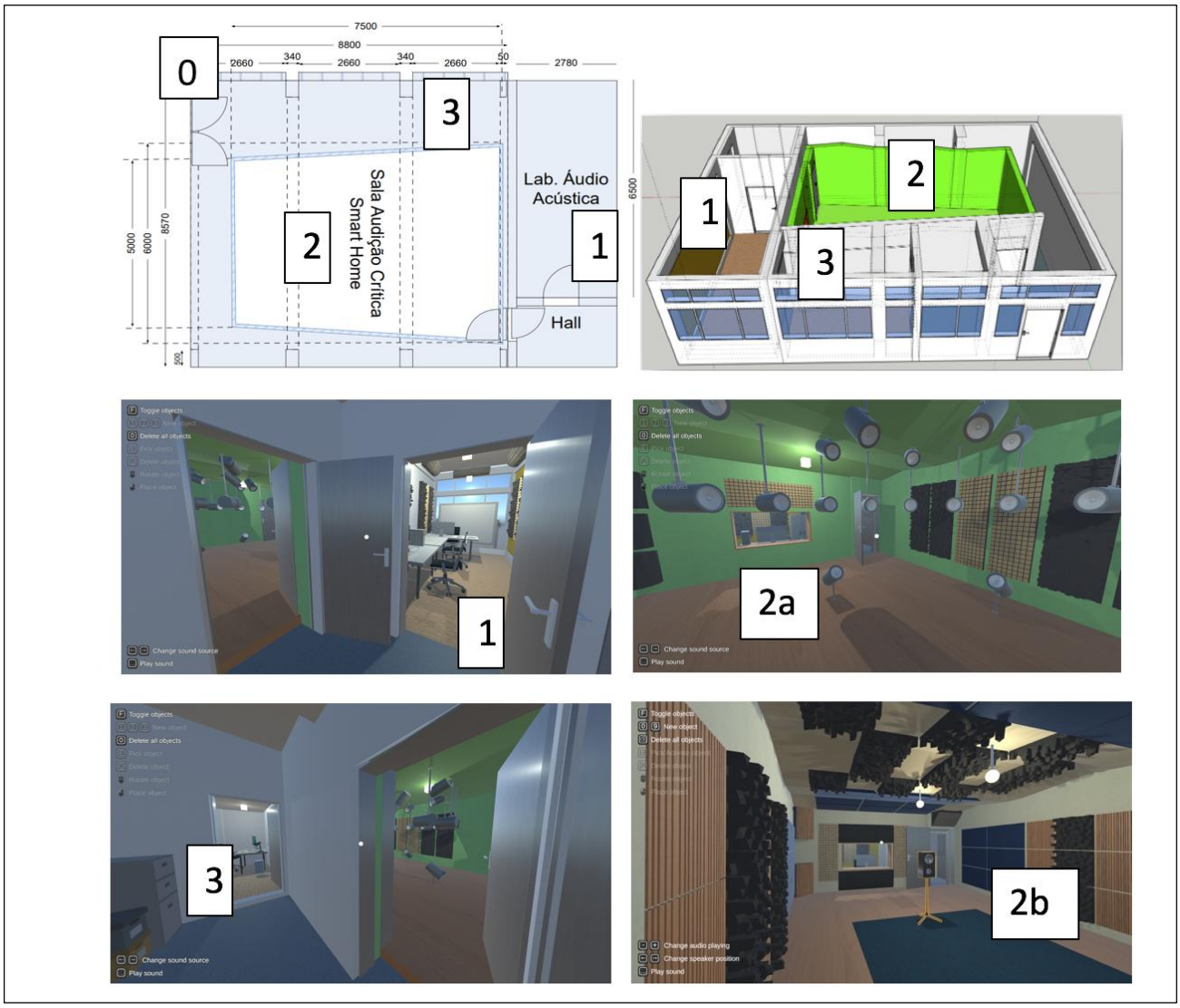

Fig. 3: Audio and Acoustics Laboratory of ISEL and rooms for activities related to sound. Global virtual model of the spaces (0), Audio and Acoustics Laboratory (1), Critical Listening Room and Immersive Sound Room, with (2a) and without multichannel sound system (2b) and Audio post-production room and workbench for audio and acoustics experiences (3).

The Laboratory of Audio and Acoustics will provide assistance to the study on a number of activities related to sound demonstrations and experiences.

4. Planned Work in progress

In this suggested study, the work is developed in several sessions where students, with the help of teachers, will essentially apply the concept of PBL.

Session 1: research administration and the sound measurement device

The teacher organizes work groups, each group addresses one scenario susceptible to cause noise annoyance in the people. For this purpose, students consider 3 possible noise contexts: Ambient Noise, Neighborhood Noise, Occupational Noise Exposure. In this way, a set of sound level values that are defined by law can be used, thus helping to build the grids with the maximum limits for each context of noise issues.

The teacher in collaboration with the students identifies each of the three noise scenarios within the school campus environment. For example: The Ambient Noise scenario can be related to road traffic noise, so the place for measurement can be at the school door, nearby the road; the Neighborhood Noise scenario is related to the transmission of sound between houses or rooms, so we can choose the wall between classrooms as a place for measurement; the Occupational Noise Exposure scenario has to do with the workers in labor place, in this way we can identify activities of the employees of the school canteen [6].

This session also serves to introduce students to the sound measurement device/app for mobile phones that will be used in the study. Thus, an explanation of its operation will be given, and students will have the possibility to familiarize themselves with the device by carrying out acoustical measurement tests inside the classroom.

Session 2: Measurements in different contexts

Students organized in groups and perform a set of acoustic measurements, with the device presented in Session 1, for each of the 3 noise contexts presented above. Photographs will be taken for each location to better identify the location.

An acoustic measurements sheet is filled with data from the sound measurements, where the location, date and time, type of context, duration of measurement, noise sources identification and additional observations, such as weather conditions, are registered.

In the end, the teacher pre-validates the data collected by the students. The pre-validation is done, in a general and simplistic way, based on several parameters, namely, the duration of each sound capture (it should be more than 10 minutes to guarantee representativeness), the average sound levels should not be, for these contexts, higher than: 70 dBA for road traffic nearby the school (Ambient Noise), 60dBA for sound transmission between classrooms (Neighborhood Noise) and 80 dBA for worker activities in the school canteen (Occupational Noise Exposure) . However, these values are only indicative, and there may be situations where there are deviations.

Session 3: Data analysis

The phase following the acoustic measurements corresponds to carrying out an analysis of the various existing noise contexts and producing conclusions.

Firstly, a pre-processing of the data/sound measurements is carried out to extract high level information, namely, sound levels (average, background noise, peak), noise spectra, spectrograms, histograms and a subjective analysis of the type of noise, like, very or little unpleasant, irritating, sharp, rough, etc.

Then, based on the preparation made previously, an objective evaluation of the results is made, comparing with the recommendations/existing legislation. This procedure allows students to gain sensitivity to the harmful effects of noise on human beings. These results also allow us to formulate a set of measures/recommendations for noise mitigation in these contexts, namely, to apply noise control approaches or quite simply as to make people aware in order to change attitudes and ways of carrying out their activities.

The conclusions produced here will allow the development of publicity material, namely the poster and brochures that will be made available to the public.

The teacher reminds students about the relevance of the study and supports each group in preparing tables, graphics and then promotes a debate around the results.

Session 4: Field trip to the laboratory of Audio and Acoustics of ISEL

In this session students visit the laboratory of Audio and Acoustics of ISEL, to highlight sound/noise issues by carrying out live experiences related to sound. Additionally, some demonstrations will be implemented. This field trip allows students to have more data available to complement the study outputs (poster/scientific presentation and infographic).

5. Conclusions and Expected Outcomes

Literature and similar projects suggest evidences of increasing motivation and engagement of students, turning them a living part of the learning process.

In addition to improving the mastery of technical skills, Project-Based Learning has another important advantage: it allows the development of socio-emotional skills indispensable for the future, such as creativity, problem solving and teamwork.

Problem-based learning brings diverse benefits in education, such as, Stimulates student activity, Forms autonomous individuals, Develops cognition, Develops the ability to work in a team and Increases the sense of responsibility.

6. Acknowledgements

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